

Reliability Metrics and Reliability Value-Based Planning

Joseph H. Eto

Lawrence Berkeley National Laboratory

Distribution Systems and Planning Training
for New England Conference of Public Utility Commissioners, Sept. 27-29, 2017

Overview of this presentation

- ▶ Reliability Metrics
- ▶ Major Events
- ▶ Reliability Value-Based Planning
- ▶ The Interruption Cost Estimate (ICE) Calculator
- ▶ Considerations for Reliability Planning Emerging from Recent LBNL Research
- ▶ Bibliography

Electricity reliability is measured by the average total time and frequency that the lights are out

System Average Interruption Duration Index

$$\text{SAIDI} = \frac{\text{total duration of sustained customer interruptions } (\geq 5\text{min each})}{\text{number of customers served}}$$

System Average Interruption Frequency Index

$$\text{SAIFI} = \frac{\text{frequency of sustained customer interruptions } (\geq 5\text{min each})}{\text{number of customers served}}$$

Customer Average Interruption Duration Index

$$\text{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}}$$

Information Reported to EIA for 2015

IEEE Standard 1366	Investor Owned	Cooperative	Municipal
Number of utilities reporting	137	296	117
% of U.S. sales by type of utility	51%	47%	43%
SAIDI with Major Events	237	302	115
SAIDI without Major Events	136	159	50
SAIFI with Major Events	1.4	2.8	0.9
SAIFI without Major Events	1.2	2.1	0.7

IEEE Standard 1366

- ▶ First developed in 1998 to define reliability indices; amended in 2003 to add a consistent approach for segmenting Major Event Days (amended again in 2012; MED definition unchanged)
- ▶ Uses $2.5 \times \beta$ to estimate a threshold daily SAIDI, T_{med} , above which a Major Event Day is identified
 - $T_{med} = \exp(\alpha + 2.5\beta)$
 - Beta = log-normal standard deviation
 - Alpha = log-normal statistical mean
- ▶ For a normal distribution:
 - Multiplying beta (the standard deviation) by 2.5 covers 99.379% of the expected observations (assuming a one-sided confidence interval)
 - For a year of daily observations, this translates to an expectation of 2.3 Major Event Days per year

Introducing Reliability Value-Based Planning

- ▶ The pace of electricity grid modernization efforts will be determined by decisions made by electric utilities, their customers, and local communities/states to adopt new technologies and practices
- ▶ An important motivation for these actions will be maintaining or improving the reliability and resiliency of electric service
- ▶ From an economic perspective, the justification for these actions will therefore, depend, at least in part, on:
 - ❑ The cost of the actions under consideration;
 - ❑ The impact they are expected to have on reliability or resilience; and
 - ❑ The value these impacts have to the utility, its customers, and the community/state
- ▶ Better information will enable, but does not guarantee, better decisions—and remember... we will never have perfect information

Value-Based Reliability Planning is a means for taking the cost of interruptions borne by customers into utility planning decisions

Mohan Munasinghe

The Economics of Power System Reliability and Planning

Theory and Case Study

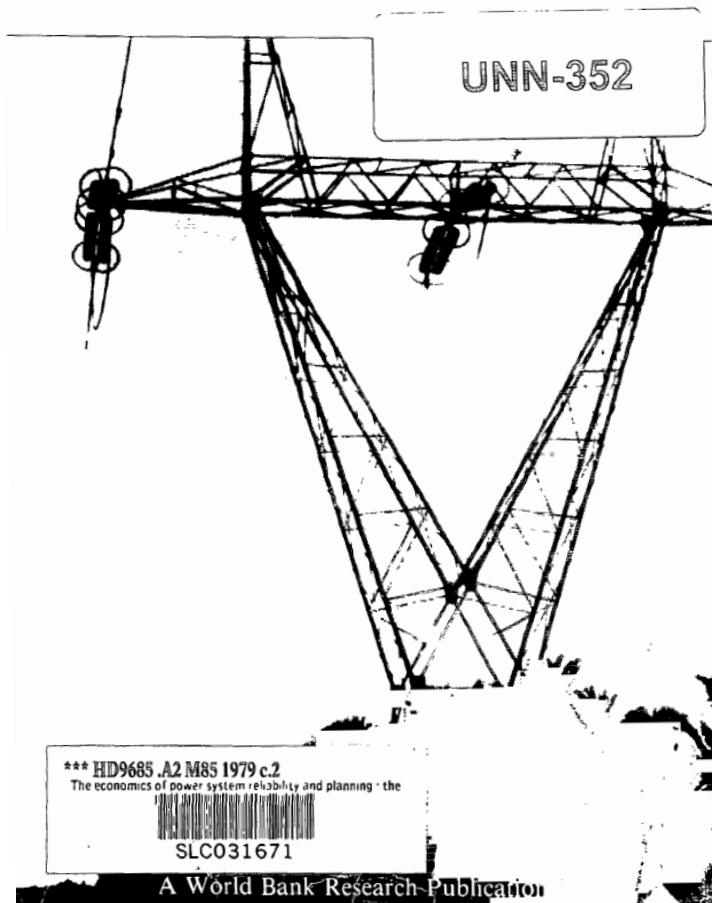
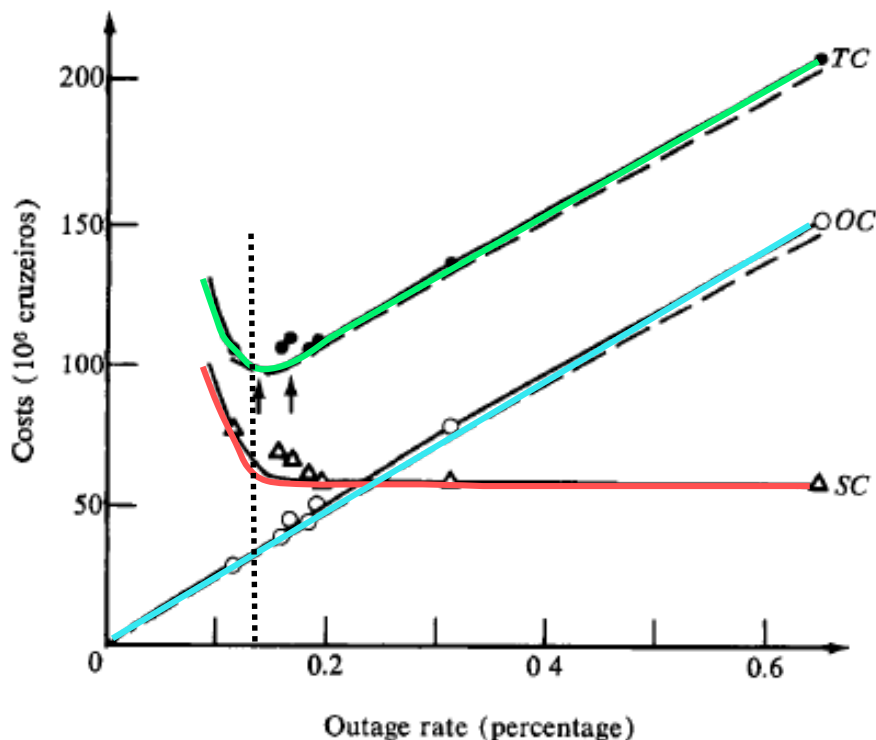


Figure 13.1. *Optimization of the Outage System: Costs Versus Outage Rate*



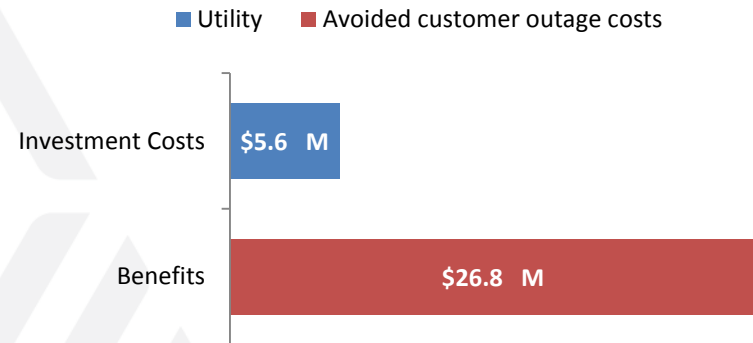
Note: SC = distribution system supply costs; OC = global outage costs; and TC = total costs. The plotted data points and solid lines refer to efficiency priced costs; the broken lines indicate the costs in terms of social prices.

Value-Based Reliability Planning example: Distribution Automation

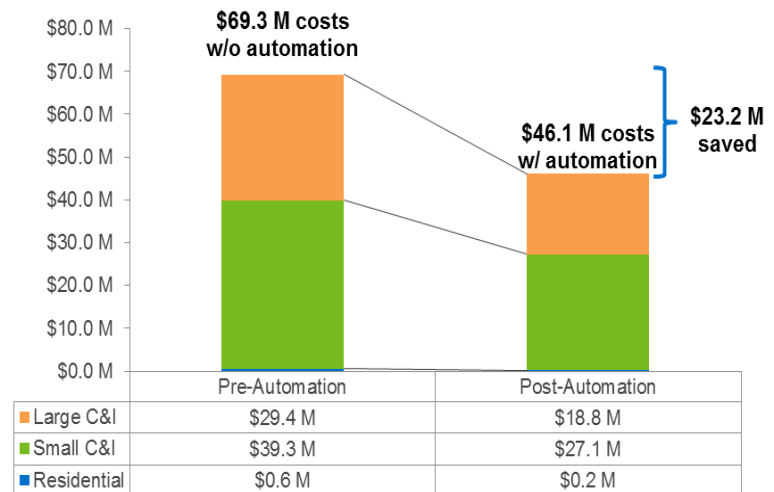
- ▶ **Utility:** EPB of Chattanooga
- ▶ **Customers Impacted:** 174,000 customers (entire territory)
- ▶ **Investment:** 1,200 automated circuit switches and sensors on 171 circuits
- ▶ **Reliability Improvement:**
 - SAIDI ↓45% (from 112 to 61.8 minutes/year)
 - SAIFI ↓51% (from 1.42 to 0.69 interruptions/ year)

(between 2010 and 2015)

Annual Costs and Benefits



Avoided Cost of Severe Storm



ICE Calculator: <http://icecalculator.com>



ICECalculator.com

Interruption Cost Estimate Calculator



The Interruption Cost Estimate (ICE) Calculator is a tool designed for electric reliability planners at utilities, government organizations or other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements.

[Home](#)

[About the Calculator](#)

[Disclaimer](#)

[Relevant Reports](#)

[Contact Us](#)

Use the ICE Calculator to:

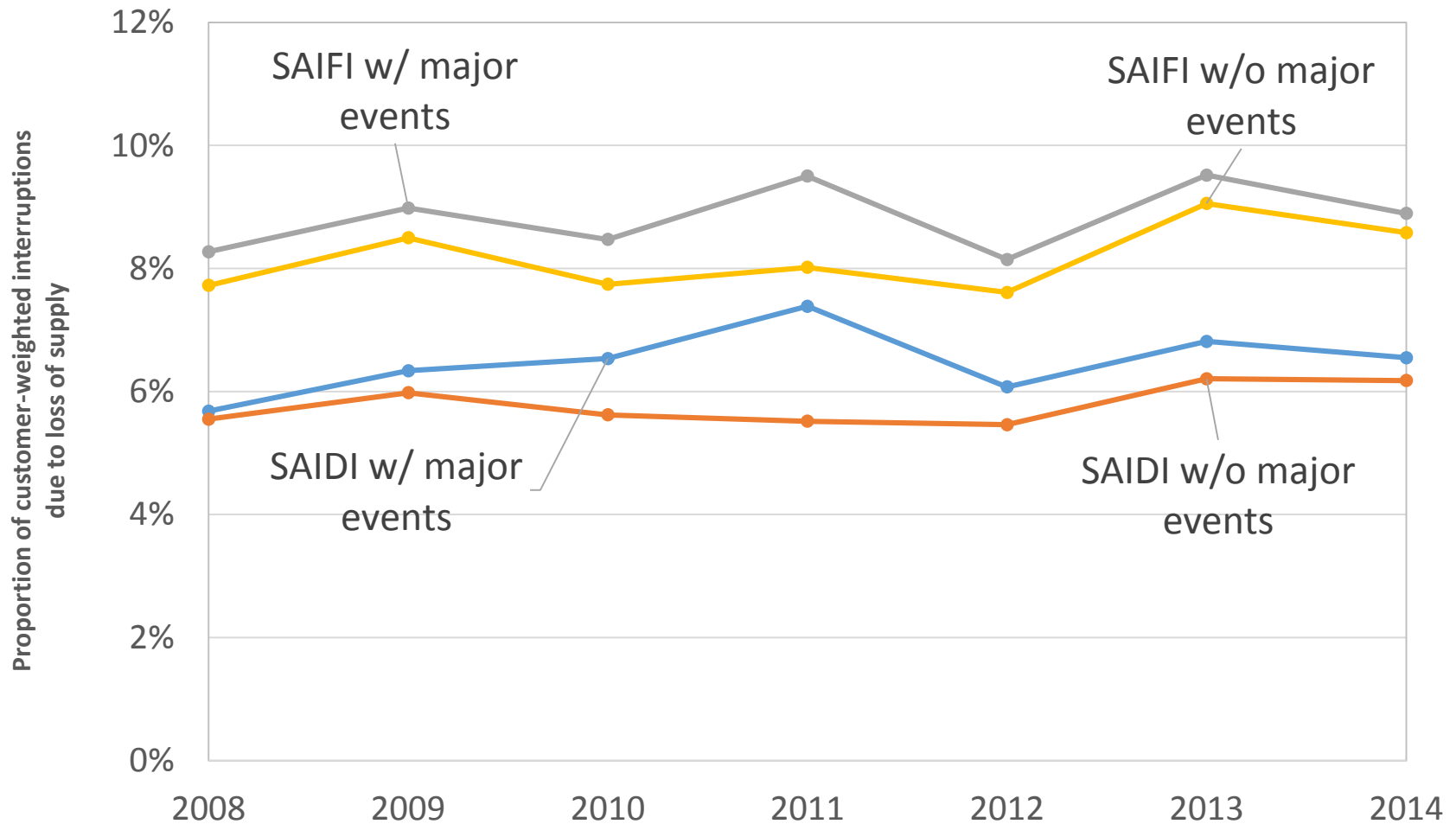
- [Estimate Interruption Costs](#)
Estimate the cost per interruption event, per average kW, per unserved kWh and the total cost of sustained electric power interruptions.
- [Estimate Value of Reliability Improvement in a Static Environment](#)
Estimate the value associated with a given reliability improvement. The environment is "static" because the expected reliability with and without the improvement does not change over time.
- [Estimate Value of Reliability Improvement in a Dynamic Environment](#)
Estimate the value associated with a given reliability improvement. The environment is "dynamic" because the expected reliability with and without the improvement changes over time based on forecasts of SAIFI, SAIDI and CAIDI.

This tool was funded by the [Lawrence Berkeley National Laboratory](#) and [Department of Energy](#). Developed by [Freeman, Sullivan & Co.](#)

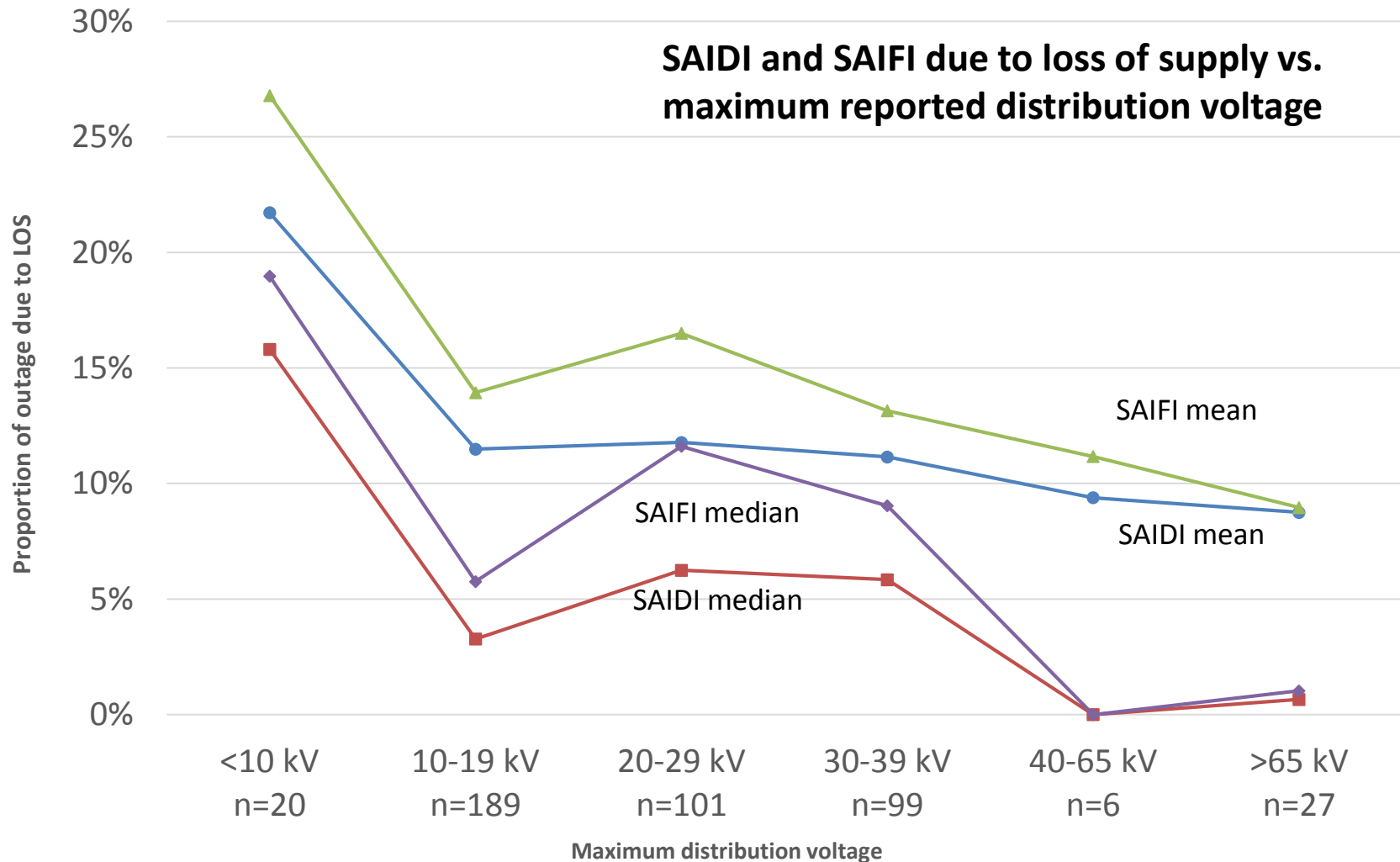
Learn more about the federal initiatives that support the development of the technologies, policies and projects transforming the electric power industry on [SmartGrid.gov](#).

Copyright 2011

Customer-weighted proportion of SAIDI and SAIIFI due to loss of supply (2008-2014, n = 73)

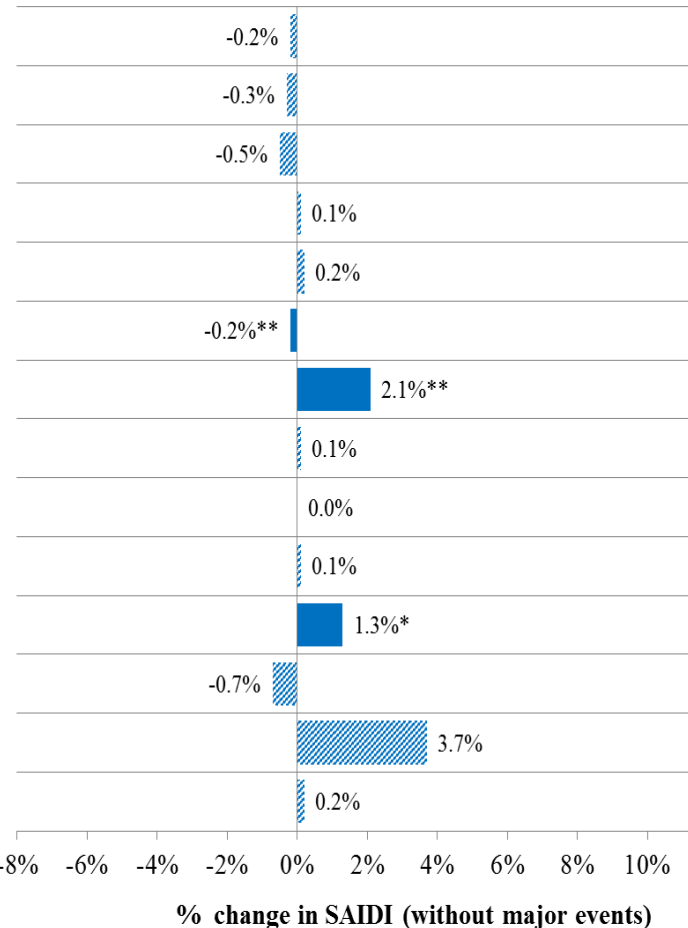


Still, we are moving in the right direction... yet, there remains much work to be done

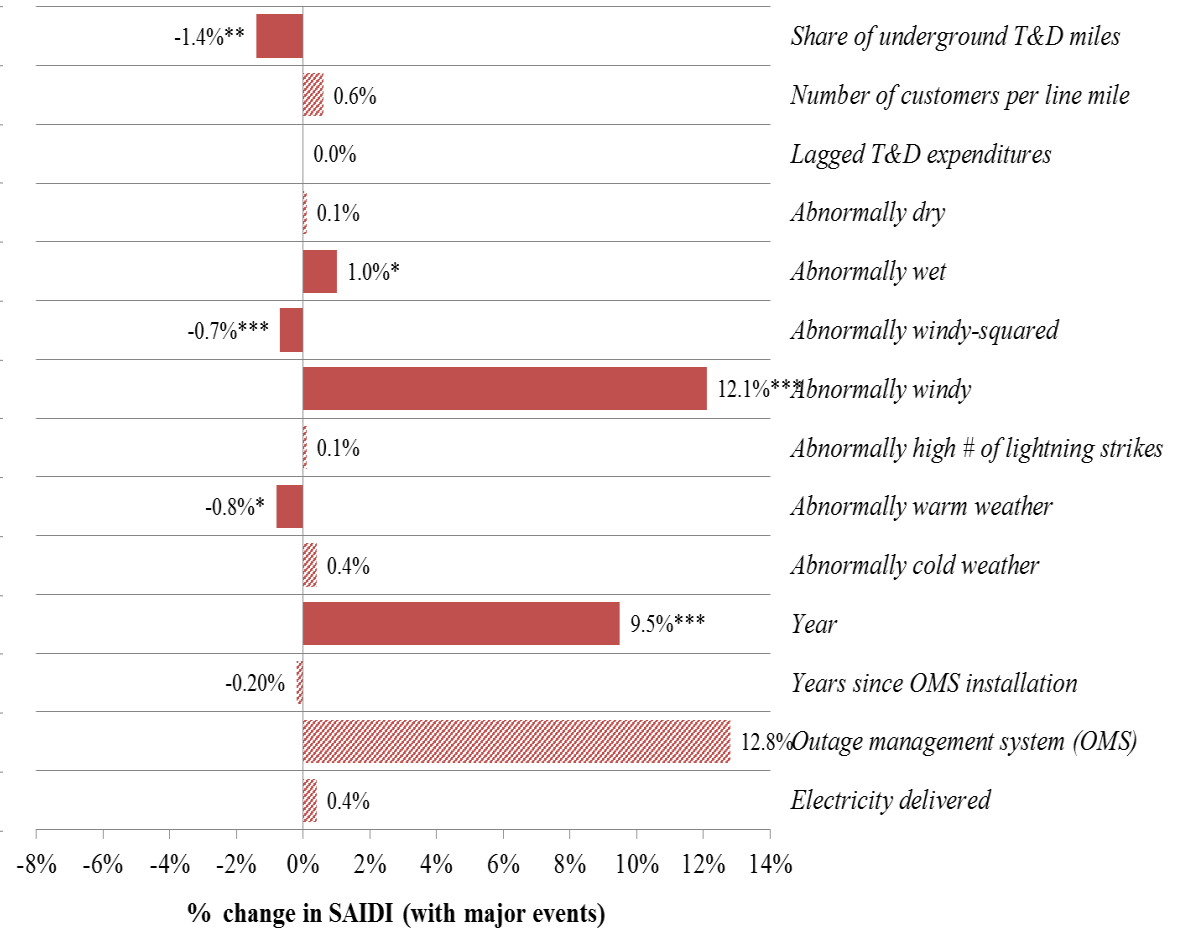


LBNL finds that reliability is getting worse due to increased severity/frequency of major events

Model F (base)



Model F (base)

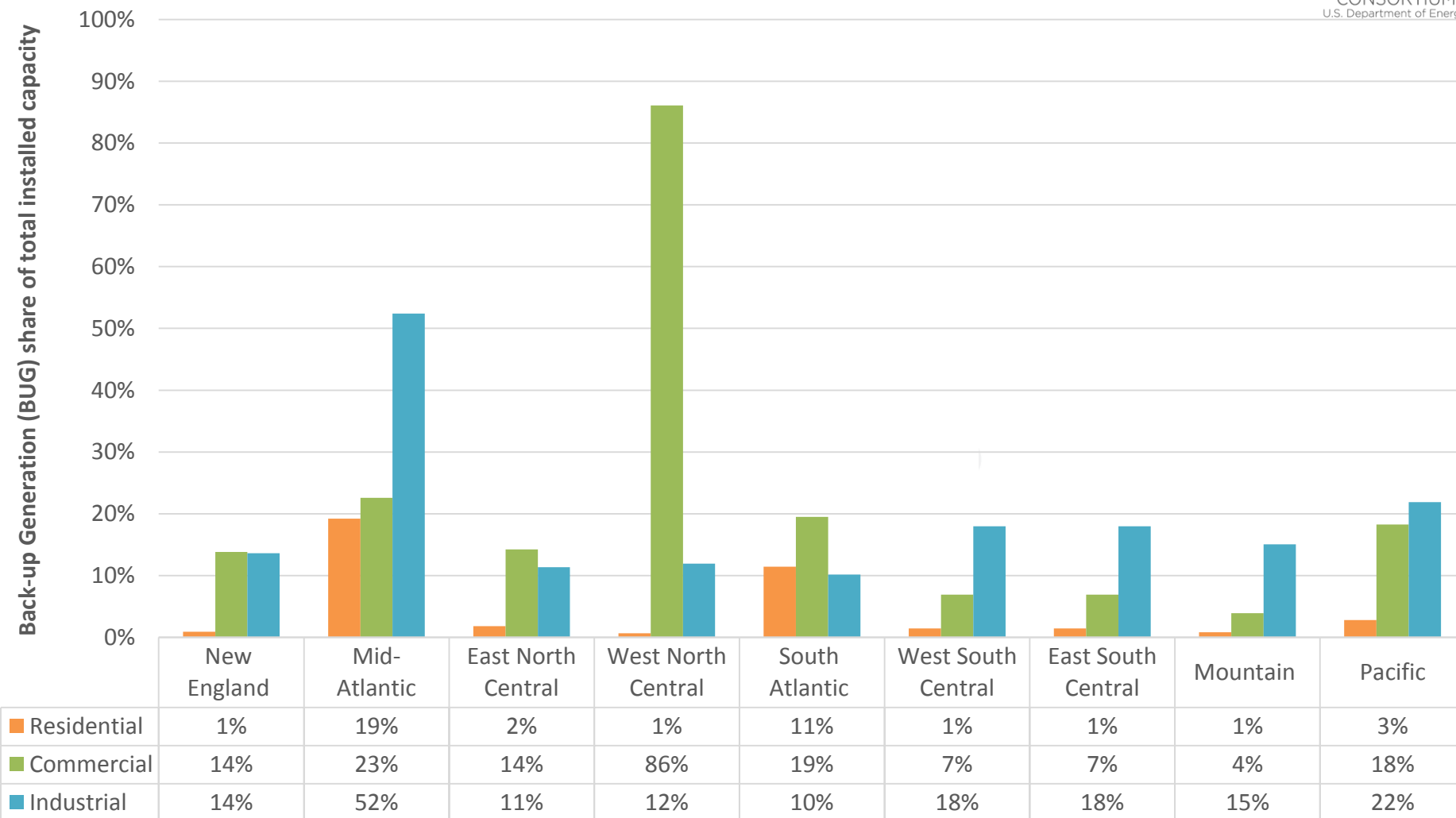


The Costs of Power Interruptions

Varies by type of customer and depends on when and for how long their lights are out

Interruption Cost	Interruption Duration				
	Momentary	30 minutes	1 hour	4 hours	8 hours
Medium and Large C&I					
Morning	\$8,133	\$11,035	\$14,488	\$43,954	\$70,190
Afternoon	\$11,756	\$15,709	\$20,360	\$59,188	\$93,890
Evening	\$9,276	\$12,844	\$17,162	\$55,278	\$89,145
Small C&I					
Morning	\$346	\$492	\$673	\$2,389	\$4,348
Afternoon	\$439	\$610	\$818	\$2,696	\$4,768
Evening	\$199	\$299	\$431	\$1,881	\$3,734
Residential					
Morning	\$3.7	\$4.4	\$5.2	\$9.9	\$13.6
Afternoon	\$2.7	\$3.3	\$3.9	\$7.8	\$10.7
Evening	\$2.4	\$3.0	\$3.7	\$8.4	\$11.9

Installed Capacity of Back-up Generation



Some themes to keep in mind

“What's measured improves”

— [Peter F. Drucker](#)

“Delegating your accountabilities is abdication”

— [Michael E. Gerber](#)

“Not everything that can be counted counts,
and not everything that counts can be counted”

— [Albert Einstein](#)

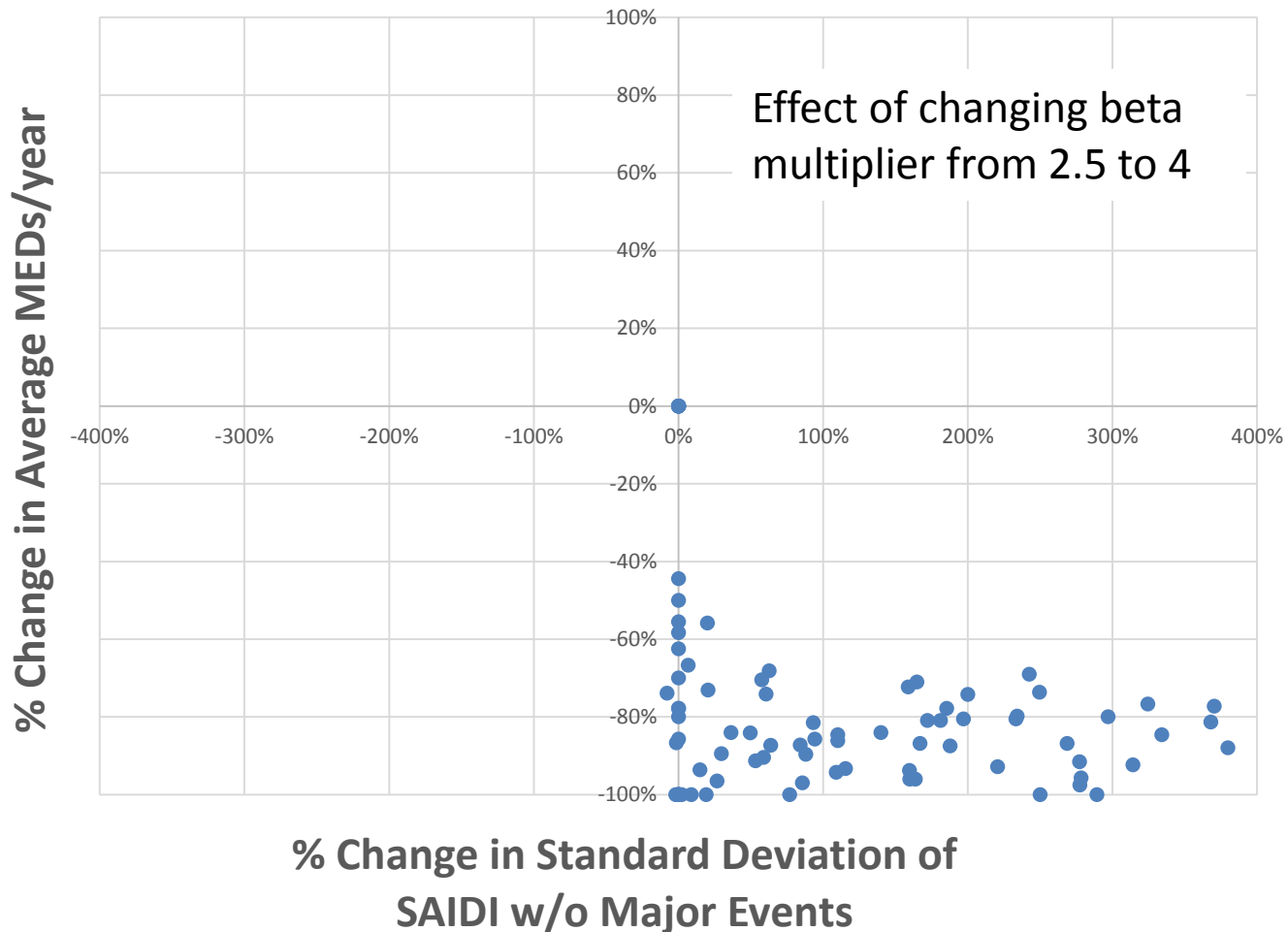
Bibliography

- ▶ [LaCommare, Kristina Hamachi, Peter H. Larsen, and Joseph H. Eto. *Evaluating Proposed Investments in Power System Reliability and Resilience: Preliminary Results from Interviews with Public Utility Commission Staff.*, 2017. <https://emp.lbl.gov/sites/default/files/lbnl-1006971.pdf>](#)
- ▶ [Larsen, Peter H. "A Method to Estimate the Costs and Benefits of Undergrounding Electricity Transmission and Distribution lines." *Energy Economics* 60, no. November 2016 \(2016\): 47-61. \[https://emp.lbl.gov/sites/default/files/lbnl-1006394_pre-publication.pdf\]\(https://emp.lbl.gov/sites/default/files/lbnl-1006394_pre-publication.pdf\)](#)
- ▶ [Larsen, Peter H., Kristina Hamachi LaCommare, Joseph H. Eto, and James L. Sweeney. *Assessing Changes in the Reliability of the U.S. Electric Power System.*, 2015. <https://emp.lbl.gov/sites/default/files/lbnl-188741.pdf>](#)
- ▶ [Eto, Joseph H., Kristina Hamachi LaCommare, Michael D. Sohn, and Heidemarie C. Caswell. "Evaluating the Performance of the IEEE Standard 1366 Method for Identifying Major Event Days View Document." *IEEE Transactions on Power Systems* 32, no. 2 \(2016\).](#)
- ▶ [Sullivan, Michael J., Josh A. Schellenberg, and Marshall Blundell. *Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States.*, 2015. <https://emp.lbl.gov/sites/default/files/lbnl-6941e.pdf>](#)
- ▶ <https://emp.lbl.gov/research/electricity-reliability>

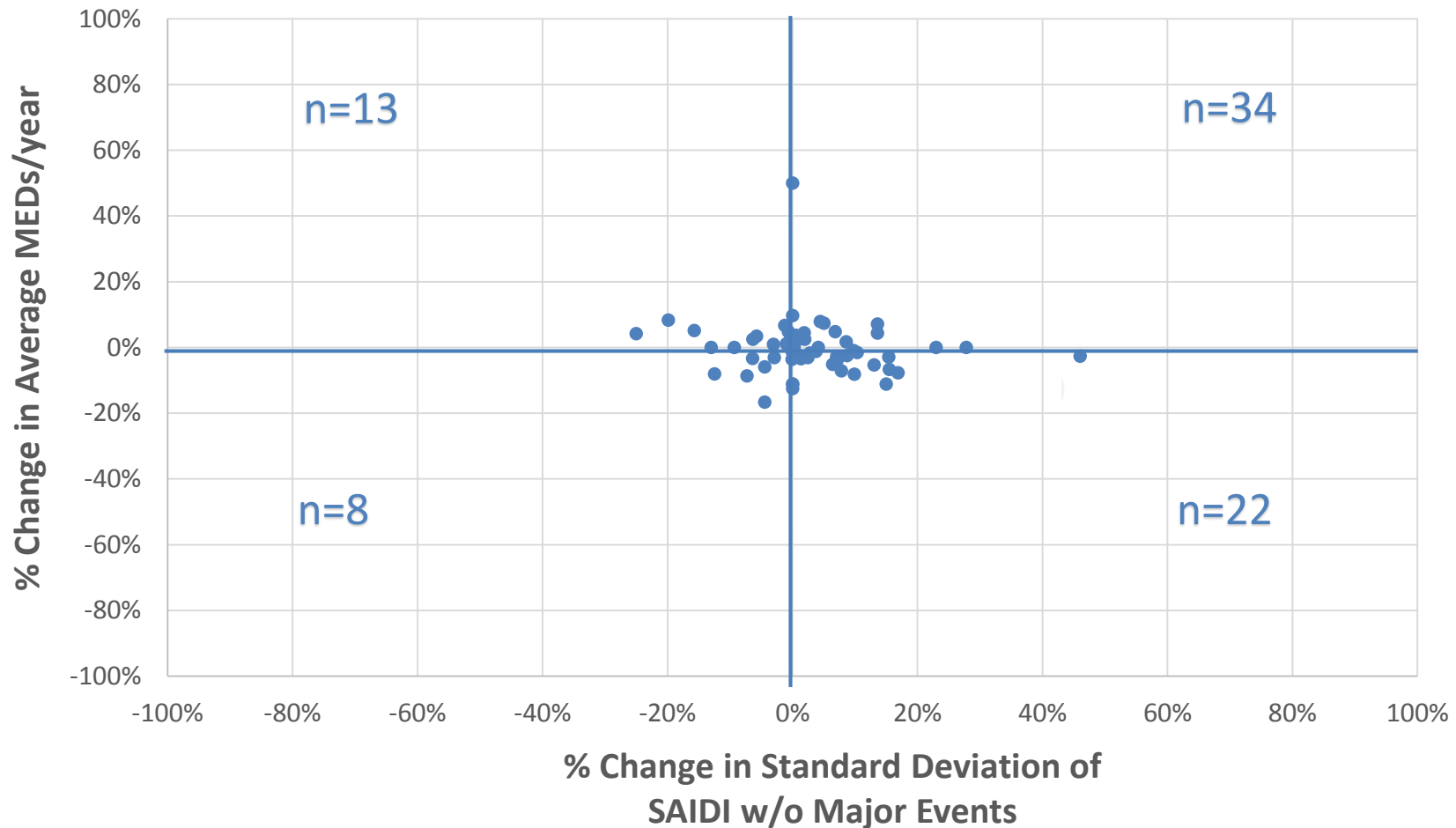
Supporting Slides



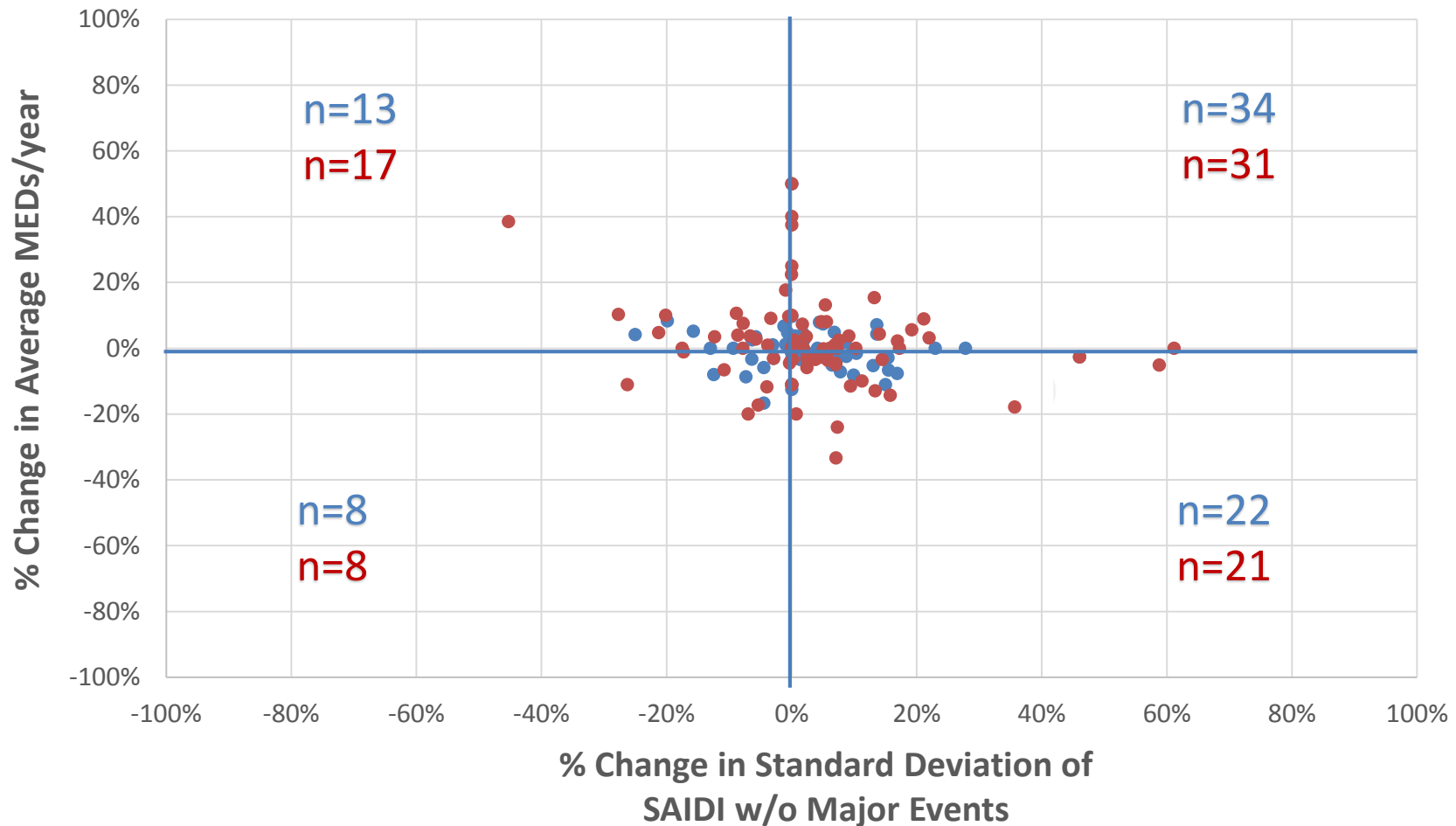
Evaluating the performance of alternatives to the Standard 1366 method



The effect of using fewer historical years to calculate Tmed: 4 years



The effect of using fewer historical years to calculate Tmed: 4 years; 3 years



The effect of using fewer historical years to calculate Tmed : 4 years; 3 years; 2 years

